

FIG.4

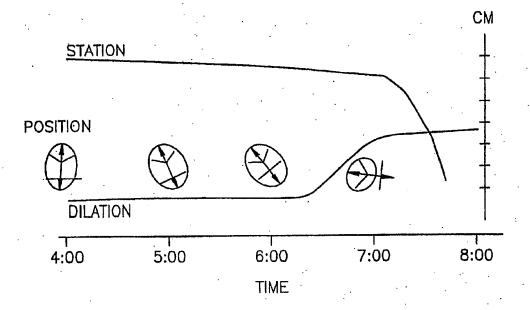
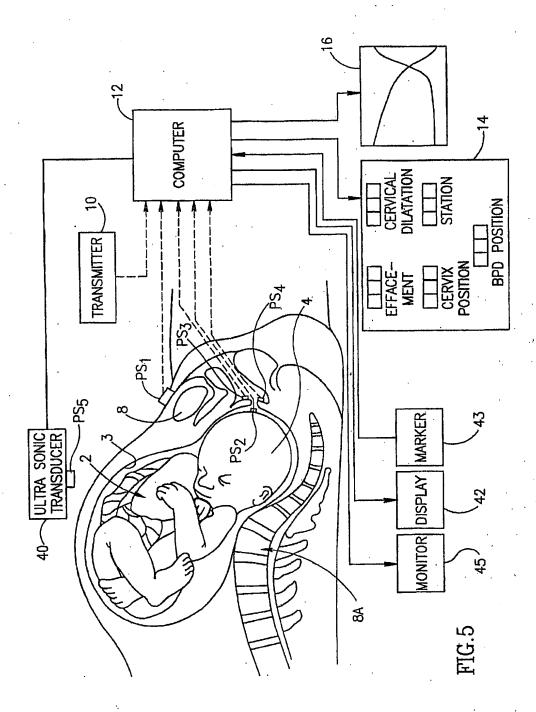


FIG.4A



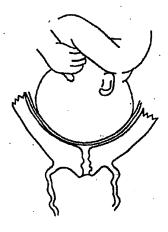


FIG.6A

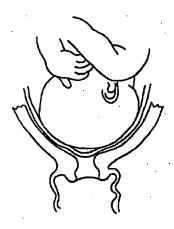


FIG.6B

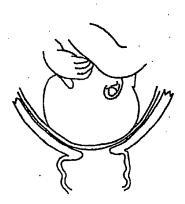


FIG.6C

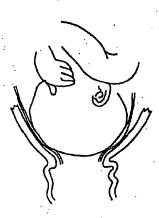


FIG.6D

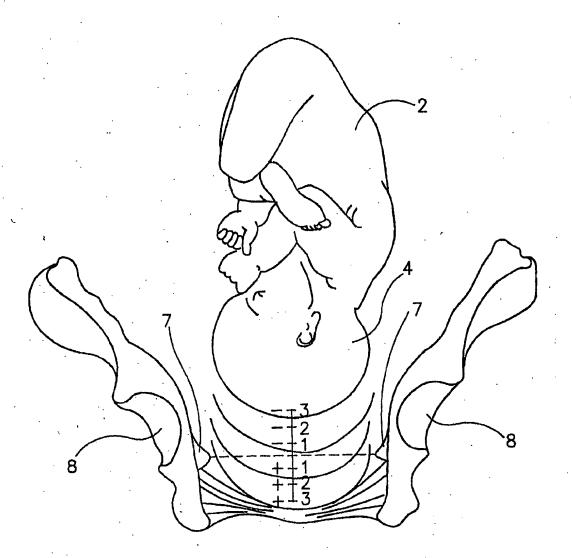


FIG.7

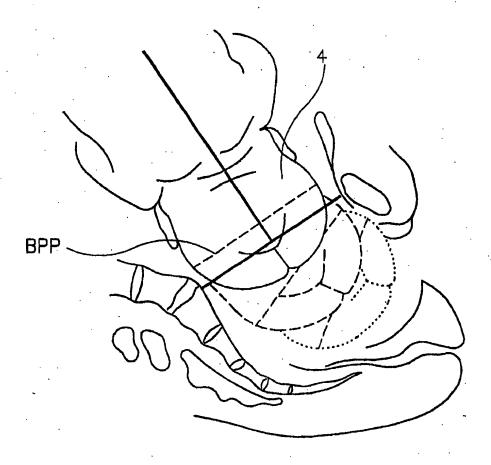
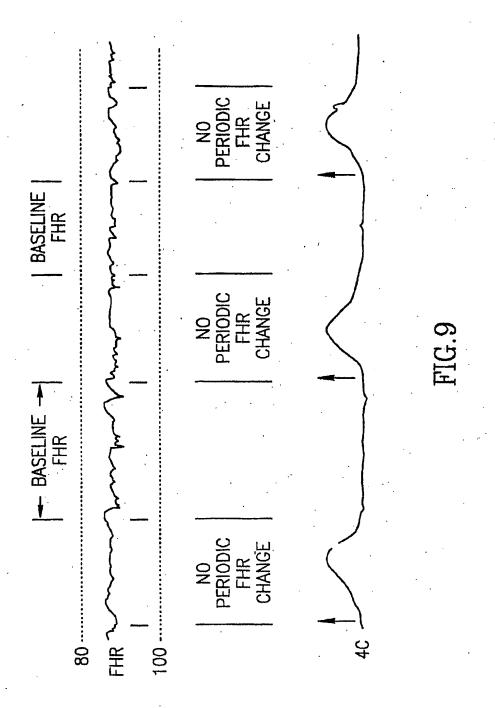


FIG.8



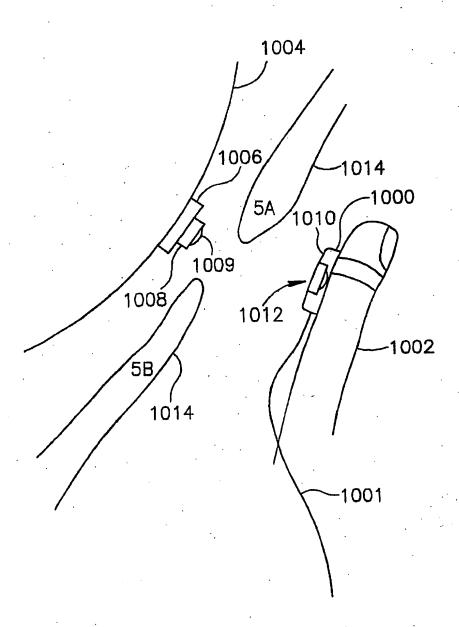


FIG.10A

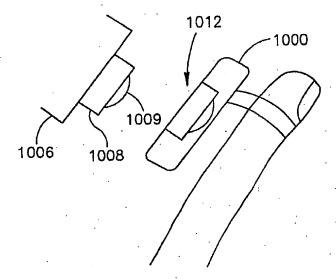


FIG.10B

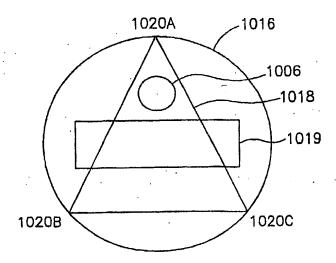


FIG.10C

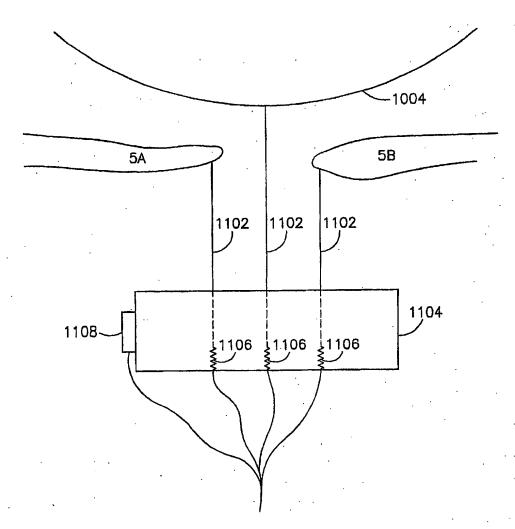
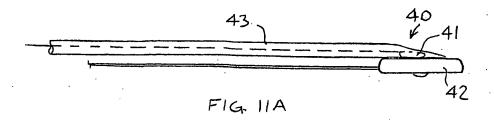
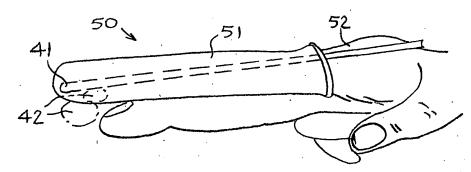
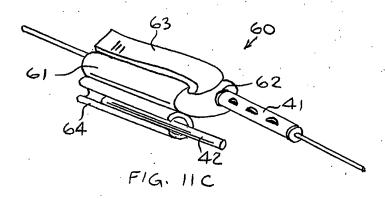


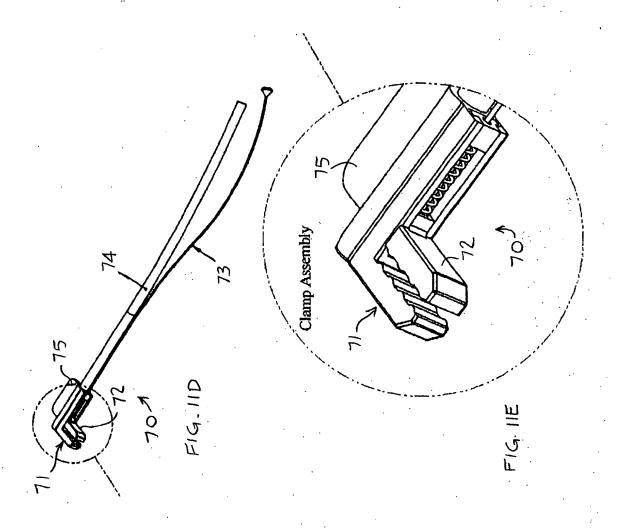
FIG.11





F1G. 11B.





DETECT A PREGNANCY COMPLICATION SIGN OR SYMPTOM -101

USE THERAPY (E.G., TOCOLYTIC AND CORTICOSTEROIDS) ~ 102
TO DELAY DELIVERY AND TO IMPROVE
FETAL SURVIVAL AND OUTCOME

PROVIDE SENSITIVE MONITORING OF ~103 THE EFFECT OF THE THERAPY

201

IDENTIFY THE EUB (EFFECTIVE ULTRASOUND BEAM) AREA

TO ENHANCE THE EUB AREA, BEFORE FINDING IT, A THRESHOLD FILTER MAY BE USED. THEN, A PREDEFINED ULTRASOUND BEAM SHAPE (RECTANGLE, TRAPEZOID, ETC.) MAY BE SOUGHT AND FOUND

IDENTIFY THE FETAL HEAD CONTOUR WITHIN THE EUB AREA ~202

ENHANCE VIDEO IMAGE

USE SMOOTHING FILTER TO PREPARE IMAGE,
FOLLOWED BY A CONTRAST ENHANCEMENT FILTER

ENHANCE CONTOUR OUTLINE RELATIVE TO REST OF IMAGE 204

USE ELLIPSE MASK TO FIND FETAL HEAD CONTOUR 205

MOVE, ROTATE AND/OR SCALE AROUND THE BOUNDING 206
RECTANGLE OF ELLIPSE MASK
UNTIL A BEST MATCH WITH IMAGE PIXELS IS FOUND

IDENTIFY BPD SIGNATURE WITHIN FETAL HEAD CONTOUR 207

SEARCH BPD SIGNATURE IN CONTOUR AREA 208

CALCULATE FIRST APPROXIMATION OF
SIGNATURE POSITION AND SIZE
BASED ON CONTOUR POSITION AND SIZE

USE IMAGE ENHANCEMENT THAT ENHANCES BPD SIGNATURE 210

- IDENTIFY FETAL HEAD VOXELS ~401

DEFINITION OF FETAL HEAD ELLIPSOID 403

DEFINE EXPECTED SURFACE BY 404
3D QUADRATIC FORM,
SECOND ORDER COEFFICIENTS

CALCULATE RESIDUAL COEFFICIENTS ~ 405 USING STANDARD DEVIATION METHOD

MAXIMUM OF 6 SETS OF COEFFICIENTS ~ 406 THAT DEFINE THE DESIRED SURFACE

CHOOSE SET THAT MOST STRICTLY DEFINES AN ELLIPSOID 407

PARAMETERS 408
OF ELLIPSOID
STABILIZE?

BPD IDENTIFICATION ~409

CONVERSION OF THE ELLIPSOID EQUATION 410
TO CANONICAL FORM YIELDS VECTORS
OF THE ELLIPSOID AXES
AND ITS PARAMETERS VALUES

DEFINE FACE ORIENTATION / 411
AND BPD ORIENTATION AND PARAMETERS

DEFINE ELLIPSOID CROSS-SECTION 412

DRAW ELLIPSE ON ULTRASOUND IMAGES 413
FOR CONTROL AND CLEAR VISUALIZATION
OF THE FETAL HEAD

OPEN WINDOW OF ULTRASOUND PROBE 7414 ON BPD PLANE TO VISUALIZE FETAL HEAD BPD CROSS-SECTION

SAMPLE (COLLECT) ULTRASONIC IMAGES ALONG WITH 3D POSITIONAL DATA AND CALIBRATION INFORMATION

SELECT SINGLE IMAGE AND MARK FETAL SKULL

1403

PROJECT MARKED FETAL SKULL IMAGE ONTO ANOTHER ULTRASONIC IMAGE, WHICH REPRESENTS A DIFFERENT PLANE IN THE 3D SPACE

THE PROJECTION MAY BE DONE BY ANY ONE OF THE FOLLOWING METHODS OR SUITABLE COMBINATION THEREOF:

A PROJECTING THE MARKED CONTOUR TO THE NEW PLANE USING PERPENDICULAR PROJECTION (STEP 1404).

B. PROJECTING TWO SURROUNDING CONTOURS, ONE INTERNAL TO THE MAIN CONTOUR (INNER) AND ONE EXTERNAL (OUTER) (STEP 1405).

C. CREATING LINE SEGMENTS, PERPENDICULAR TO THE PROJECTED VERSION OF THE ORIGINAL CONTOUR, SPANNING FROM THE INTER CONTOUR TO THE OUTER CONTOUR (STEP 1406).

D. CREATING A NEW CONTOUR, IN THE NEW PLANE, BY SELECTING, ON EACH LINE SEGMENT, A SINGLE PIXEL USING A FUNCTION, SUCH AS BUT NOT LIMITED TO, THE MAXIMAL GRAY LEVEL, OR AN ORDERED FILTER OR SMOOTHING FILTER FOLLOWED BY AN ORDERED FILTER OR MATCHED FILTER (STEP 1407).

E. POST FILTERING THE NEW CONTOUR BY REMOVING A PORTION OF THE DARKER PIXELS IN THE CONTOUR (STEP 1408).

F. POST FILTERING THE NEW CONTOUR BY CALCULATING AN ELLIPSE THE BEST MATCHES THE NEW CONTOUR POINTS AND THEN REMOVING POINTS WHICH LAY TOO FAR FROM THAT ELLIPSE (STEP 1409).

1410

TRANSLATE CONTOURS FROM 2D CONTOURS
ON AN ULTRASONIC IMAGE INTO THEIR TRUE 3D LOCATION USING THE
CALIBRATION INFORMATION

FIG. 14A

APPROXIMATE BPD PLANE BASED ON 301 OTHER WELL-DEFINED PLANE

CALCULATE BPD PLANE USING 302 3D TRANSFORMATION OF THIS PLANE, BASED ON KNOWN ANATOMICAL RELATIONSHIPS

APPROXIMATE BPD PLANE BASED ON FETAL HEAD 3D CONTOUR 303

LOCATE FETAL HEAD AND SHIFT ULTRASOUND BEAM 304
ACROSS FETAL HEAD, CAPTURING HEAD
BOTTOM-UP OR TOP-DOWN

PROCESS IMAGES AND FIND 2D CONTOURS 305 AND OTHER WELL KNOWN OBJECTS IN THE FETAL HEAD

CONSTRUCT 3D CONTOUR (E.G. ELLIPSOID) 306
BY SUPERPOSITION OF 2D CONTOURS,
WHILE EXTRAPOLATING THE MISSING PARTS

CALCULATE BPD PLANE RELATIVE TO 3D MODEL 307

APPROXIMATE BPD PLANE
BASED ON FETAL HEAD STRETCH MODEL 308

LOCATE FETAL HEAD AND SHIFT ULTRASOUND BEAM 309 ACROSS FETAL HEAD, CAPTURING HEAD BOTTOM-UP OR TOP-DOWN

PROCESS IMAGES AND FIND 2D CONTOURS 310
AND OTHER WELL KNOWN OBJECTS IN THE FETAL HEAD

STRETCH 3D MODEL OF FETAL HEAD 311
TO FIT THE ELEMENTS FOUND

CALCULATE BPD PLANE RELATIVE TO 3D MODEL 312

CONSTRUCT A 3D MODEL OF FETAL HEAD 501

MODEL PELVIC INLET BY AN ELLIPSE WITH A MAJOR AXIS AND A MINOR AXIS

GET FETAL HEAD ORIENTATION 503

CHECK SET OF SLICES (IN THE FETAL HEAD PLANES) 504

FOR EACH ELLIPSE ALONG THE PATH TO THE PELVIC INLET, CALCULATE MAJOR AND MINOR AXES

FOR EACH ORIENTATION VECTOR N, CALCULATE THE LARGEST AXIS DIMENSIONS

DEFINE LIMITED SET OF PHYSICALLY POSSIBLE ORIENTATIONS 507

CALCULATE SURPLUS DIMENSIONS

AMONG ALL ENABLING ORIENTATIONS, THE ONE WITH LARGEST AVERAGE SURPLUS DIMENSION IS CHOSEN AS BEST POSSIBLE

FIG. 16

ORIENTATION

601

MAP BODY PARTS BY USING EXTERNAL LOCATION SENSORS

∕ 602

USE EXTRAPOLATION, MODEL STRETCHING OR OTHER ALGORITHMS
TO DETERMINE INTERNAL OR GLOBAL CHARACTERISTICS OF BODY
PARTS OUTSIDE OF PELVIC REGION

FIG. 17

701 MAP BODY PARTS BY USING EXTERNAL ULTRASOUND TRANSMITTER

. 702

USE EXTRAPOLATION, MODEL STRETCHING OR OTHER ALGORITHMS
TO DETERMINE INTERNAL OR GLOBAL CHARACTERISTICS OF BODY
PARTS OUTSIDE OF PELVIC REGION